International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

# Exploration of Special Properties of AL 5056/CNT Metal Matrix Nano-Composites

**B. Madhusudhana Reddy, Anand P**

***Abstract*: *Over the two decades, researchers and manufacturers of automotive and aerospace appliances have paid much attention and interest to metal matric composites (MMC) due to their unique properties. This paper focus on the special characteristics of Metal Matrix Composites of Aluminum Al5056 reinforced with Carbon Nano Tube (CNT) in different weight ratios of 0.4%, 0.7% and 1.1% of base material. Stir-casting technique is utilized to prepare the composites in line with ASTM standards. The specimens are tested for electrical conductivity, corrosion and wear features. Further the internal structure of these composites is studied by using the SEM Analysis. It is found from the results that by adding reinforcement the composites are affected and SEM analysis of AMMNCs reveal a uniform distribution of CNT in the alloy of Aluminum.***

***Index Terms*: *CNT, microstructure characterization, Nano composites, Stir-casting furnace.***

## I. INTRODUCTION

Alloys of Aluminum have low density, good resistance to corrosion and wear, better mechanical features, less thermal coefficient of expansion. The other attractive feature is that its availability in affordable cost. Due to the above qualities, alloys of aluminum are extensively utilized in structural, aerospace and automobile industries. Along with the above properties, the tensile strength and electrical conductivity are needed for the composite material. It is observed that CNT is treated as filler due to its properties like high tensile strength high conductivity and carbon fibers reinforced Aluminum matrix is of great interest. To address this issue, this paper is attentive on preparation and testing of properties of CNT reinforced Al 5056, called Aluminum Metal Matrix Nano Composites (AMMNCs).

Nikhilesh Chawla et al. [1] recognized the need for metal matrix composites which are reinforced with particle based material. They captured the salient features of experimental and computational characterization of the developed composite by focusing mainly on wrought particulate armored light alloy systems of tensile, creep and fatigue activities. Mares M et al. [2] carried investigations on power-driven and wear stuff of some hybrid nano aluminum matrix composites. The investigation was carried by varying nature and content of particulate. Jasmi Hashim et al. [3] established the A359/Sic MMC with stir casting charted by a 2-step stirring action. The stirring was done before pouring into a mold. This mechanism carries the advantage with respect to the promotion of wettability between the Al359 matrix alloy and the silicon carbide particle. Vukcevic M et al. [4] had studied the new developments in materials and processes and provided the information that is helpful for commercial usage of these materials in market and finally concluded that an increased interest on Hybrid nano metal matrix composite.

Warren H. Hunt et al. [5] observed the necessity of metal matrix material among various matrix material. Aluminum is the far most preferred and material of contender reinforcement include $Al_2O_3$, SiC, TiC, $B_4C$, Graphite, $TiB_2$ and many other ceramics. These ceramic are made available in three classes. They are chopped fiber or whisker, continuous fiber and particulate. Hyunjoo C. et al. [6] carried investigations on the reinforcing effects of the carbon nano tubes for aluminum matrix. They used the different wt% of CNT like 1.5%, 3.0%, and 4.5% MWCNT in Al matrix. Wu Shenqing and Li Jun [7] developed the piston material by doping the short fibers of silicon into Al alloy and treated as new kind of material for automobile pistons.

Stephen F. Bartolucci et al. [8] carried the works towards the fabrication of the composites with grapheme platelets and powdered aluminum by utilizing the ball milling, hot isostatic pressing and extrusion E. Mohammad Sharifi et al. [9] studied the Al-B4C nano composites properties. Powders are made by the ball milling. Umanath K et al. [10] industrialized the wear resistance, co-efficient of friction of Al-base hybrid composites reinforced with combinations of SiC and $Al_2O_3$ particles on an Al6061alloy by using stir casting scheme. Alaneme KK et al. [11, 12, 13] developed the AMC composite materials using different reinforcement material which are broadly categorized into 3 sets. They are synthetic ceramic particulates, industrial wastes and derivatives of agro waste. M. Tabandeh-Khorshid et al. [14] fabricated the Aluminum metal matrix nano composites reinforced by grapheme nanoplates synthesized by powder metallurgy method. Performed investigations for tribological behavior of developed composites and studied the tribological conditions. Anis Micheal Visu. A. et al. [15]

Revised Manuscript Received on 30 July 2019.
* Correspondence Author
**B Madhusudhan Reddy***, Research Scholar, Dept. of Mechanical Engineering, Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology, Chennai, India.
**Dr. Anand P**, Associate Professor, Dept. of Mechanical Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, India.

prepared the Al-10%MoO3 composites and compared with a base metal of hardness, surface roughness, and corrosion properties.

Kang PyoSo et al. [16] investigated the rudimentary radiation resources discipline of MMC with a great verve ion accelerator to Helium and Aluminum ions which create atomic shifts in the compound. Isaza Merino et al. [17] studied the underpinning of magnesium sheets with MWCNT by the club sandwich method. This method is capable of generating a good dispersion of MWCNT with no indication of harmfulness. Ervina Efzan M.N. et al. [18] conducted a study focused on the appropriate and shared methods to manufacture the AMCs such as powder metallurgy, stir-casting, squeeze casting and compo-casting methods. M. Shifa et al. [19] fabricated the Hybrid honeycomb sandwich structure. This structure contains Al honeycomb core inserted between multi-scale reinforced epoxy composite facing and performed the mechanical properties. Rajesh et al. [20] performed the investigation on Al6061/CNT which are prepared by the method of ultrasonic stir casting furnace.

SEM report revealed that uniform distribution of CNT reinforcement in base Al alloy. Veeresh Kumar G.B et al. [21] studied the features of mechanical and wear deeds of Al-MMCs and the forecasting mechanical and tribological properties of Aluminum MMCs.

## II. MATERIALS

The Al 5056 matrix material is used in this work due to its vast applications in many sectors. The elemental composition of alloy is listed below (Table.1). Reinforcement used is CNT particles of average particle size are about 30nm. In the present work, AMMNC samples are prepared by reinforcing Carbon Nano Tube (CNT) material in different percentages (Table.2) with Al5056 base material to study its properties.

**Table1. Chemical Composition**

| | Elements of Al 5056 in percentage | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Al 5056 | Si | Fe | Cu | Mn | Mg | Cr | Zn | Al |
| | 0.3 | 0.35 | 0.1 | 0.1 | 4.0 | 0.05 | 0.1 | 95 |

**Table 2: Physical properties of CNTs**

| Property | SWCNT (single walled CNT) |
|---|---|
| Thermal Conductivity (W/(m K)) | 6000 |
| Electrical Conductivity (S/cm) | $10^2$-$10^6$ |
| Specific Gravity (g/cm3) | 0.8 |
| Electron Mobility (cm2/(V s)) | $10^5$ |
| Coefficient of thermal expansion (K-1) | Negligible |
| Thermal stability in air (centigrade) | >600 |

## III. PREPARATION AND TESTING OF AMMNCs

### A. Corrosion Testing of AMMNCs

The weight-loss test is the most effective scheme of predicting corrosion-losses. The testing procedure is as follows. The sample size of 50×10×5 $mm^3$ is cut from the AMMNCs and the weight of the sample specimen is measured. Each sample has to immerse separately in 3.5% NaCl solution after the surfaces are polished up to 600 Grit finished. The weight loss for each sample will be determined after immersion of two months.

The corrosion rates can be calculated with the following formulae.

Corrosion-rate = ( WL × K ) / ( ρ × A × T) (1)

where WL is Weight-loss of AMMNC in grams (g), ρ is AMMNC density ($g/cm^2$), T is Exposure time (hr) and A is Exposed Area ($cm^2$)

**Table 3. Constant for calculation of corrosion rate**

| Desired corrosion rate unit | Area unit (A) | K-Factor |
|---|---|---|
| mils/year (Mils penetration per year) | $inches^2$ | $5.34\times10^5$ |
| mils/year (Mils penetration per year) | $Centi\text{-}meter^2$ | $3.45\times10^6$ |
| millimeters/year (mmy) | $Centi\text{-}meter^2$ | $8.75\times10^4$ |

- MPY: Mils penetration per year i.e. (1/1000) of inch

**Table 4: Corrosion rate of AMMNCs**

| Sample number | Composition | Corrosion rate (mpy) |
|---|---|---|
| 1 | Al5056 | 0.422 |
| 2 | Al5056+0.4%CNT | 0.396 |
| 3 | Al5056+0.7%CNT | 0.367 |
| 4 | Al5056+1.1%CNT | 0.361 |

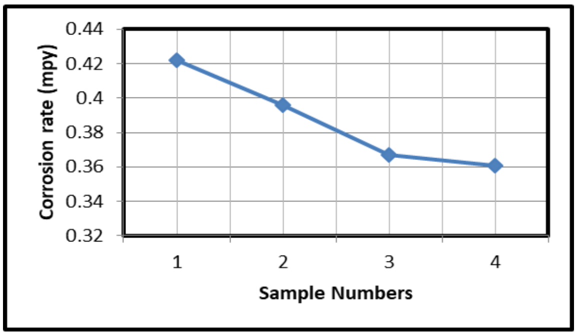


**Fig. 1 Corrosion rate Vs Sample Numbers**

The corrosion rates are represented against the sample numbers and are drawn in Fig 2. It is evident that if the percentage weight of the CNT reinforcement raised, the corrosive resistance is also increased for the composites.

### B. Wear Testing of AMMNC

The dry sliding wear tests were performed using pin - on - disc gadget, shown in Fig. 3 on test tasters of size 10×10mm square pin. The samples of the Al Metal Matrix Composites are evaluated for weight loss by using pin-on-disc apparatus at 3kg load, 80mm track diameter and 1500rpm speed of disc. The test surface was polished on different grades of abrasive paper to ensure the proper contact with hard steel disc. Each specimen is then weighed using a digital balance having an accuracy of ±0.0001 gm, after that the specimen is mounted on the pin holder of the tribometer ready for wear test.

Sliding wear tests were conducted at different load, speed, track diameter and time.

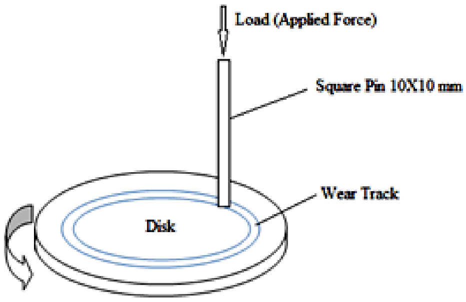


**Fig. 2 Representation of Pin-On-Disc Wear Procedure**

The sliding wear loss was measured and the wear rate and wear factor was calculate as:

$$Wear\ Rate = \frac{V_W}{(\pi \times d_t \times N \times T)} \quad (2)$$

where $V_w$ is wear volume, $d_t$ is track diameter, N is disc speed and T is time.

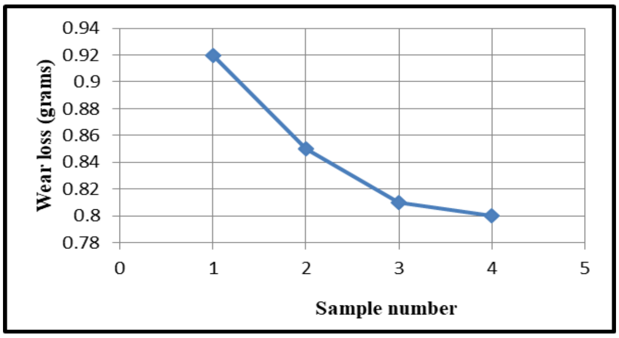


**Fig. 3 Corrosion rate Vs Sample Numbers**

$$Wear\ Rate = \frac{V_W}{(F \times V \times T)} \quad (3)$$

where $V_w$ is wear volume, F is applied force, V is rubbing velocity, and T is time.

**Table 5: Wear values of AMMNCs**

| Sample number | Composition | Wear loss (grams) |
|---|---|---|
| 1 | Al5056 | 0.92 |
| 2 | Al5056+0.4%CNT | 0.85 |
| 3 | Al5056+0.7%CNT | 0.81 |
| 4 | Al5056+1.1%CNT | 0.80 |

It is clear from Fig 3 that with an increase in percentage of reinforcement, the weight loss of composites is decreased. It is evident from the above graph that the minimum weight loss was observed in Al5056+1.1% CNT (15% reduced) and maximum weight loss is observed in Al alloy.

### C. Electrical Conductivity of AMMNC

Four probe technique is used to determine the resistivity of AMMNCs. The experiment can be done with the help of probe arrangement, oven 0-200°C, sample, constant current generator, oven power supply and digital panel meter.

Four probe equipment is one of the standard and most widely used equipment for the measurement of resistivity of semiconductors. This method is employed when the sample is in the form of a thin wafer, such as a thin semiconductor material deposited on a substrate. The sample is millimeter in size and having a thickness w. It consists of four probe arranged linearly in a straight line at equal distance S from each other. A constant current is passed through the two probes and the potential drop V across the middle two probes is measured. An oven is provided with a heater to heat the sample so that behavior of the sample is studied with increase in temperature.

At constant temperature, the resistance, R of a conductor is proportional to its length L and inversely proportional to its area of cross section A and ρ is the resistivity of the conductor, its unit is ohmmeter.

$$R = \rho \frac{L}{A} \quad (4)$$

When temperature starts increasing, the occupancy of conduction band is also increasing and results in a decrease in electrical resistivity of semiconductor.

$$\rho_0 = \frac{V}{R} 2\pi S \quad (5)$$

The AMMNCs containing various percentages of CNTs are evaluated for measuring electrical conductivities using four probe techniques. The same is evident in the above graph. From the above graph it can be observed that the electrical conductivity of the composite increases with the improvement in reinforcement material.

**Table 6: Electrical conductivity of the AMMNCs**

| Sample number | Composition | Conductivity($\Omega^{-1}$/mm) |
|---|---|---|
| 1 | Al5056 | 0.573 |
| 2 | Al5056+0.4%CNT | 0.741 |
| 3 | Al5056+0.7%CNT | 1.272 |
| 4 | Al5056+1.1%CNT | 1.283 |

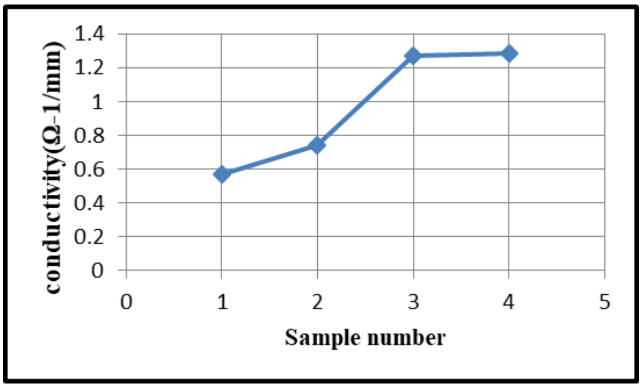


**Fig 4: Conductivity Vs Sample Numbers**

## IV. SEM ANALYSIS OF AMMNC

The type of reinforcing particles and distribution of these particles influences the mechanical properties of AMMNCs. To achieve good possessions of material, particles should be uniformly distributed. This distribution should carried out throughout the AMMNCs.

Solidification rate, type of reinforcement, fluidity and the method of casting process are the variables which directs the distribution of particles. By using Scanning Electron Microscope, the structures of the samples taken from the casting at different locations have been observed. The SEM Images for each specimen are shown in Fig. 5 to Fig. 7. The images of SEM are showing a uniform distribution of reinforcing particles.

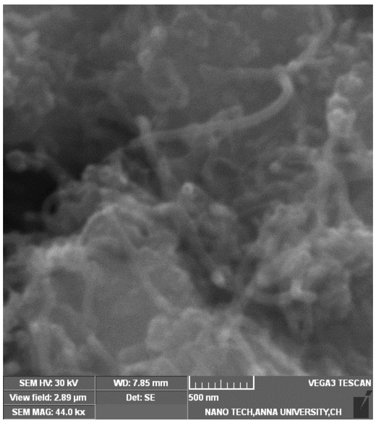


**Fig. 5 Al 5056+ 0.4% CNT**

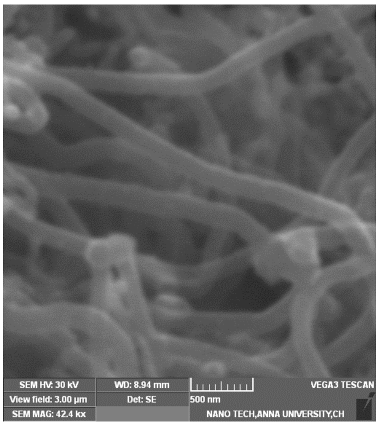


**Fig. 6 Al 5056+ 0.7% CNT**

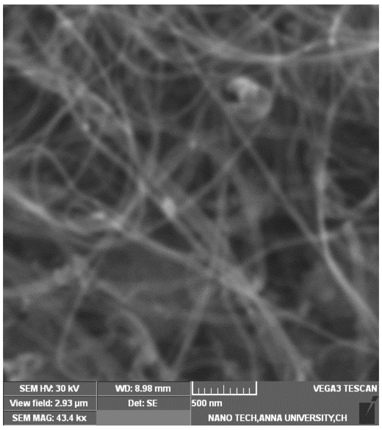


**Fig. 7 Al 5056+ 1.1% CNT**

## V. CONCLUSIONS

It can be concluded that there are specific improvements in the properties like corrosion rate, wear loss and electrical resistance with an increase of reinforcement in the Aluminium base material and the reason for the specific improvements in the properties is that the reinforcement in the aluminium base metal is uniformly distributed. Further, it is concluded that the CNT is the best reinforce material for improving the properties of Al5056 which has major applications in the manufacturing and aviation industries.

## REFERENCES


1. N. Chawla and Y. Shen, "Mechanical Behavior of Particle Reinforced Metal Matrix Composites," Advanced Engg. Mat., 3, no. 6, (2001), pp.357-370
2. Mares M., "Some Issues on Tailoring Possibilities for Mechanical Properties of Particulate Reinforced Metal Matrix Composites," JOAM, vol. 3, no. 1, March (2001), pp. 119 – 124.
3. J. Hashim, "The Production of Cast Metal Matrix Composite by a Modified Stir Casting Method," JurnalTeknologi, 35(A) Dis. (2001), pp. 9–20.
4. V. M, and D. K., "Some New Directions in Aluminum Based PM Materials for Automotive Applications," Materiali in Tehnologue, (2002) 36, pp. 101-105.
5. W. H. Hunt and D. R. Herling, "Aluminum Metal Matrix composites," Adv. Mat.s & Proc., February (2004), pp. 39-42.
6. H. Choi, J. Shin, and B. Min, "Reinforcing effects of carbon nanotubes in structural aluminum matrix nanocomposites," Mat. Res. Soc., journals.cambridge.org. , vol. 24, no. 8, Aug 2009.
7. W. Shenqing and L. Jun, "Application of ceramic short fiber reinforced Al alloy matrix composite on piston for internal combustion engines," China Foundry, vol. 7, no. 4, (2010).
8. S. F. Bartolucci, J. Paras, M. A. Rafiee, J. Rafiee, S. Lee, D. Kapoor and N. Koratkar, "Graphene–aluminum nanocomposites," Mat. Sci. and Engg., A 528 (2011), pp. 7933– 7937.
9. E. M. Sharifi, F. K. and M. H. Enayati, "Fabrication and evaluation of mechanical and tribological properties of boron carbide reinforced aluminum matrix nanocomposites," Mat. and Des., 32 (2011), pp. 3263–3271.
10. U.K., S. T. Selvamani, K. Palanikumar, "Friction and Wear Behavior of Al6061 Alloy (SiCp + $Al_2O_3$) Hybrid Composites," IJEST, vol. 3, no. 7, July (2011), pp. 5441- 5451.
11. KK. Alaneme, AO. Aluko, "Fracture toughness (K1C) and tensile properties of as-cast and age-hardened aluminum (6063)–silicon carbide particulate composites," Sci Iran (2012), 19(4), 992–6.
12. KK. Alaneme, MO. Bodunrin, "Mechanical behavior ofalumina reinforced Aa 6063 metal matrix composites developed by two step – stir casting process," Acta TechCorvininesis – Bull Eng (2013), 6(3), 105–10.
13. KK Alaneme, AO. Aluko, "Production and age-hardening behavior of borax premixed SiC reinforced Al-Mg-Si alloy composites developed by double stir-casting technique," West. Indian. J. of Eng. (2012), 34(1–2), 80–5.
14. M. Tabandeh-Khorshid, E. Omrani, P. L. Menezes, P. K. Rohatgi, "Tribological performance of self-lubricating aluminum matrix nano composites: Role of graphenenanoplatelets," EST, (2015).
15. A. Micheal V. A, N. A.M, Balaji. A.N, "Mechanical and Corrosion Properties ofAl5034-Moo3 Metal Matrix Composite," IJIRSET, vol. 3, Special Issue 3, March 2014.
16. K. PyoSo, D. Chen, A. Kushima, "Dispersion of carbon nanotubes in aluminum improves radiation resistance", Nanoenergy, ScienceDirect, 2015.
17. C.A. I. Merino et al., "Metal matrix composites reinforced with carbon nanotubes by an alternative technique," J. of All. and Comp. (2016).
18. E. Efzan M.N. et al., "Fabrication Method of Aluminum Matrix Composite (AMCS): A Review," TTP, Switzerland (2018), vol. 700, pp. 102-110.
19. M. Shifa et al., "Effect of Carbon Nanotubes on Mechanical Properties of Honeycomb Sandwich Panels" The Nucleus 54, no. 1 (2017), pp. 1-6.
20. N. Rajesh and M. Yohan, "Fabrication and Mechanical Properties of Aluminum Metal matrix nano composite (AL6061/CNT)," ARPN, vol.13, no. 23, Dec 2018.
21. V. Kumar G.B et al., "Mechanical and Tribological Behavior of Particulate Reinforced Aluminum Metal Matrix Composites," JMMCE (2011), vol. 10, no.1, pp. 59-91.


*Retrieval Number B1965078219/19©BEIESP*
*DOI: 10.35940/ijrte.B1965.078219*
*Journal Website: www.ijrte.org*



*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*

## AUTHOR'S PROFILE

**Mr. B. Madhusudhana Reddy is** working as an Assistant Professor in the Department of Mechanical Engineering at NBKRIST, Vidyanagar, SPSR Nellore District, Andhra Pradesh, India, since 2010. He Completed his M.Tech from SV University, Tirupati. Currently, he is doing his research in the area of Composite Materials under the guidance of Dr. P. Anand, Associate Professor in the department of Mechanical Engineering at VEL Tech. Dr. RR and Dr. SR R&D Institute of Science and Technology, Chennai-T.N, India.

**Dr. P. ANAND** is presently working as an Associate Professor in the Department of Mechanical Engineering in VEL Tech. Dr. RR and Dr. SR R&D Institute of Science and Technology, Chennai-T.N, India. He completed his Bachelors at Sethu Institute of Technology in 2005, Masters in Mechanical Engineering – CAD at Alagappa Chettiyar College of Engineering & Technology in 2009 and received Doctoral degree in Mechanical Engineering from Anna University in 2015. His research interest include composite materials, finite element analysis and engineering design.